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# Soft X-ray Imaging Telescope on ASTROSAT

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**Abstract.** A Soft X-ray focusing Telescope (SXT) with an X-ray sensitive CCD camera at the focal plane is being developed for the ASTROSAT. Made from conical foil mirrors with a CCD detector in the focal plane, SXT will have a reflecting area of ~200 cm$^2$ below 1.5 keV, angular resolution of ~3'-4'(FWHM) at 1.5 keV, energy bandwidth of 0.3 – 8 keV and energy resolution of about 150 eV. A brief description of the SXT design and development, and science expected from it after its launch is given.

*Keywords* : X-rays – instrumentation – sources

## 1. Introduction

A Soft X-ray imaging Telescope (SXT) is one of the X-ray instruments (see other articles in these proceedings) chosen to be part of ASTROSAT – an Indian multiwavelength astronomy satellite planned for launch in early 2006. Soft X-ray telescopes are based on the principle of total reflection from smooth metallic (high Z) surfaces at glancing (critical) A set of coaxial and confocal shells of paraboloidal and hyperboloidal mirrors are used to focus X-rays (see Wolter 1952a,b). X-rays are first reflected by an internally reflecting paraboloidal mirror and then reflected to the prime focus of the telescope by the internally reflecting hyperboloid mirror in Wolter I design. At grazing incidence, the active region of the mirror is just a thin annulus giving a small collecting area even for a large diameter mirror. Thus nesting of shells is incorporated to improve the filling factor of the circle defined by the outermost shell. Higher nesting is achieved by using shells made of very thin foils but figured in a conical approximation to Wolter I optics (Serlemitsos 1988). Use of thin foils leads to (a) a huge saving in weight, (b) an enormous saving in cost due to the ease of fabrication, (c) higher upper energy limit, since the thin foils can be nested closer to the axis giving smaller grazing angles for reflecting higher energy photons. These advantages are, however, at the cost of spatial resolution and complexity of mounting and aligning multiple thin foils.

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## 2. Description

SXT is being designed with a focal length of 2m, constrained by the available space in the launch vehicle. The telescope will use thin shell X-ray reflecting surfaces made from gold-coated alumninum (Al) segmented foils (Serlemitsos 1988; Westergaard et al. 1985). A facility to make mirrors of this quality using a replication process where gold is first deposited by sputtering on smooth glass mandrels and then transfered to the foils, is being set up at TIFR. Each reflector will have a length of 10cm. Nearly 42 complete shells will be nested in two sections – the alpha section for the first reflection, and the 3-alpha section for the second reflection. Each section is divided into 4 quadrants, which are produced individually with an outer and inner cylinder wall connected with two sideplates. The mechanical design for holding the mirrors in correct geomtery is similar to the one used for Spectrum-X-Gamma (Westergaard et al 1990). Qualification of Al surfaces and their alignment will be done using an optical parallel beam. The surface roughness will be studied using an atomic force measurement machine. Finally, an X-ray beam will be used for overall calibration.

The focal plane of the telescope will carry a CCD based camera, based on X-ray sensitive CCDs specially developed by Marconi Applied Technolgies, UK, in collaboration with the Liecester University for the XMM/EPIC camera. The CCD has 600x600 pixels each of 40$\mu$m square, providing a plate scale of 4.13 arcseconds per pixel and a field of view of 41.3 arcminutes. The CCDs use a novel open gate design (Holland et al. 1996) to improve low energy quantum efficiency significantly in comparison with standard front-illuminated CCDs, while retaining superior low-energy resolution in comparison with the back-illuminated CCD, and have a number of radiation tolerant-design features to provide good performance over the mission lifetime. The detector will be operated at below -80 C using thermoelectric coolers and passive cooling. Cooling is required for low noise and reduced sensitivity to radiation damage. Small radioactive sources illuminate the four corners of the CCD to continuously monitor detector gain, resolution and charge transfer efficiency. The camera body will contain a fixed optical blocking filter deposited on one side similar to the filters flown elsewhere.

The camera electronics will include: power distribution boards and relays, temperature controller, Pre-amplifiers, Signal Chain board, Analog house-keeping, Clock Sequencer, Clock Drivers, CPU board, and Spacecraft Interface boards. The CCD clock waveforms will be created in digital form on the Clock Sequencer board, and translated to analog signals on the Clock driver board. CCD signals will be processed and digitised by a Signal Chain board. Three instrumental modes will be made available: Imaging, Timing and Photon counting. The Photon counting mode will be used for source spectra and photometry with full spectral resolution and sensitivity. Imaging and Timing modes are for very strong sources and will avoid detector saturation and photon pile-up.

The overall dimensions of SXT are 0.35m (dia) x 2.3 m. Total mass allowed for the payload is 86 kg. The power budget for SXT is 80 W. SXT will be mounted on the ASTROSAT to have 60 degree sun avoidance and 10 degree earth avoidance. A shutter for telescope (door), and a shutter for camera operation on the ground would be built in. The onboard memory requirement is projected to be 70 Mbytes.

## 3. Science with SXT

SXT will have the sensitivity to detect a $10\mu$Crab source in a typical exposure of about 10000s. In stronger sources ($>100\mu$Crab), SXT will be able to resolve K$\alpha$ *line emission* from Si, S, Ar, Ca and Fe in hot thermal coronal plasmas, as well as fluorescent line emission from these elements photoionised by strong X-ray continuum in accretion powered X-ray sources (Galactic black-holes, supermassive black-holes etc.). It would, therefore, be capable of probing and carrying out spectroscopy of hot thin plasmas in galaxies, clusters of galaxies, nuclei of active galaxies, quasars, supernova remnants and stellar coronae. In particular, SXT will be used for studying the physics of shocks and accretion disks, coronae, photo-ionised regions and their density, temperature, ionisation degree, and elemental abundance. Fluorescence Fe line emission in AGNs and other accreting systems, and specially, study of the response of line emission to varying ionising continuum will help to understand the dynamics of these systems. *Low energy absorption* measurements with SXT will tell us about the nature of absorbers (cold or warm). *Soft X-ray excesses* due to smooth black-body emissions in AGNs (Singh et al. 1985, 1990; Pounds et al. 2001), and in binary X-ray pulsars (Dal Fiume et al. 1998) would be studied in great detail with the SXT in conjunction with other X-ray instruments. *Spatially resolved spectroscopy* of SNRs and Clusters of galaxies are other goals where SXT is expected to play a key role.

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